

# Prevention of meconium aspiration syndrome: an update and the Baylor experience

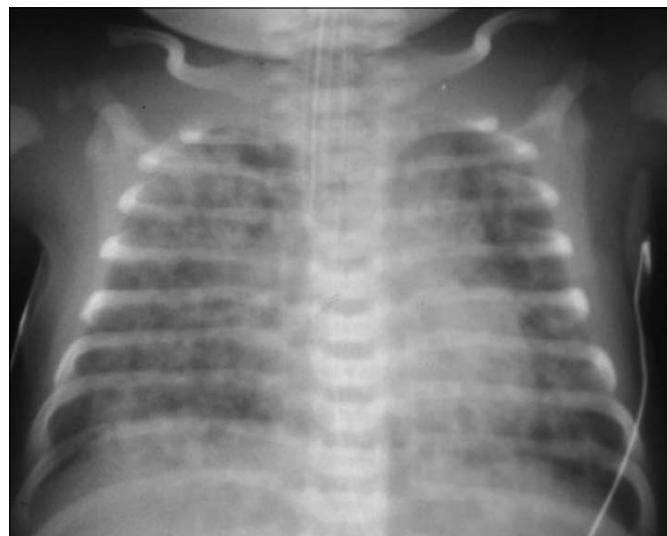
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The approach to preventing meconium aspiration syndrome (MAS) in the newborn has changed markedly over the last 30 years. In the late 1970s, all infants born through meconium-stained amniotic fluid (MSAf) had upper-airway suctioning before delivery of the shoulders and then had tracheal intubation and suctioning in the delivery room. Now suctioning of the upper airway is no longer recommended, and only “depressed” infants are intubated for tracheal suctioning. The incidence of MAS and the associated high mortality rate have both declined significantly over time. This is due to improved antepartum and intrapartum obstetrical management as well as the postdelivery resuscitation of the neonate born through MSAf. MAS is no longer considered to be solely a postnatal disorder that is preventable with routine delivery room suctioning of the trachea; rather, it is considered a complex and multifactorial disorder with antenatal as well as intrapartum factors. The incidence and severity of MAS have been positively affected by a combined obstetrical and neonatal approach to the infant born through MSAf. In this article, we detail our experience at Baylor University Medical Center with MAS and its prevention and review the current literature.

**M**econium aspiration syndrome (MAS) is a serious, life-threatening respiratory disorder of the newborn that occurs in approximately 2% to 5% of infants born through meconium-stained amniotic fluid (MSAf) (1). MAS is characterized by a diffuse parenchymal and airway disease in which meconium-induced inflammation of the lung is complicated by the mechanical effects of particulate meconium causing partial or complete airway obstruction (*Figure 1*). This combination results in severe respiratory failure, often with pulmonary artery hypertension as well as air block syndromes (pneumothorax/pneumomediastinum/pulmonary interstitial emphysema). Mortality rates have improved over the last 30 years, but rates in excess of 50% were reported in the 1960s and 1970s (2). The seriousness of this disorder has led to exploration of various preventive approaches.

## EVOLUTION OF APPROACHES

The evolution of our understanding of MAS and its prevention has paralleled the improvements in study design and rigorous peer review. The early papers on prevention of MAS were either



**Figure 1.** Chest x-ray of meconium aspiration syndrome showing bilateral diffuse patchy opacities.

retrospective or, if prospective, were not randomized. We have moved away from viewing significant associations as proof of causation. The more recent appearance of randomized prospective and controlled studies in prevention of MAS has resulted in a much improved and evidence-based change in practice.

## Development of the suctioning and intubation approach

James proposed intratracheal suctioning as a method to prevent MAS about 4 decades ago (3). The sentinel descriptive prospective delivery room study was carried out by Gregory and his colleagues (4), in which all term infants born through meconium were intubated and suctioned at birth. Although the numbers were small, they reported a 100% survival! This contrasted with the normal two to three deaths per year in their institution. This study was followed by a retrospective observational study of infants admitted to the neonatal intensive care unit (NICU) with a diagnosis of MAS (5). Survival was markedly improved in those

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infants intubated and suctioned at birth compared with those who were not intubated and suctioned in the delivery room. In 1976, Carson and colleagues in Colorado reported a nonrandomized cohort study (6) using a combined obstetrical and neonatal suctioning approach. This consisted of suctioning of the upper airway with a deLee suction device once the head was delivered but prior to delivery of the chest or shoulders, with subsequent routine laryngoscope visualization of the vocal cords and suctioning of the trachea if meconium was visualized once the baby was born. With this approach, they had no deaths (compared with historical controls of five deaths among 18 cases of MAS) and reduced the number of infants with MAS from 18 to 1.

Implicit in these approaches was the notion that MAS was a preventable *postnatal* event. Suctioning of the upper airway before delivery of the shoulders and intubation and suctioning of the trachea immediately after delivery clearly saved lives and became the standard of care.

Over the next 20 years, morbidity and mortality rates for MAS continued to decline, and a whole generation of pediatric residents honed their intubation skills in the delivery room. Slowly, however, the thinking about the prevention of MAS began to change. Was it really necessary to intubate and suction all infants born through MSAF? Did suctioning of the upper airway prior to delivery of the chest improve the outcome, or was it some other aspect of evolving intrapartum care?

A closer look at the original studies cited above is of interest in light of today's thinking about this topic. For example, in the study by Gregory and colleagues of 80 infants born through MSAF and intubated for tracheal suctioning, only 58% (46) were found to have meconium in the trachea—i.e., 43%, or 34 infants, despite being born through meconium, did not aspirate meconium into the airway, and none of them became sick. Clearly, some infants are able to protect their airway. Presumably, the more compromised fetus with hypoxia and acidosis that gasps in utero may not protect its airway and can aspirate meconium (7, 8). Even then, not all infants aspirating meconium become sick. In the study by Gregory and colleagues, among the 46 infants with evidence of aspiration, only one third (16/46) actually became sick. Whether the act of suctioning prevented MAS in the other two thirds of infants is not answerable by this study.

Nevertheless, the idea that a more selective approach to tracheal suctioning might make sense is apparent on closer look at the study by Carson and colleagues. Only two of the infants in the prospective portion of the study actually underwent intratracheal suctioning, and despite this, the mortality was low (when compared with the retrospective cohort) and the incidence of MAS dropped dramatically (see above). This was attributed at that time to the new intervention of upper-airway suctioning prior to delivery of the shoulders. This study also raises the question of other obstetrical factors at play other than the obstetrical deLee suctioning.

### Further studies that raised questions about routine intrapartum suctioning

Since the study of Carson and colleagues, the oro- and nasopharyngeal suctioning of the infant born through MSAF prior

**Table 1. Position of the Neonatal Resuscitation Program of the American Academy of Pediatrics for care of the infant born through meconium**

Guideline	1977	2000	2005
Suction upper airway before shoulders delivered	Recommended	Recommended	Not recommended
Suction trachea in all	Yes	No	No
Selective suctioning only	No	Yes	Yes

to delivery of shoulders and chest became a widespread therapy. However, several subsequent studies could not establish benefit with this therapy.

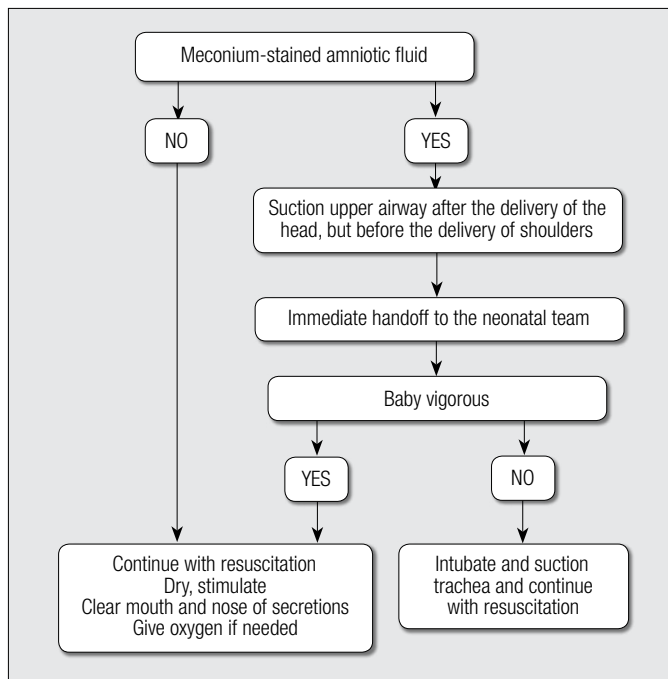
In an observational study (9), Falciglia et al compared the outcomes of two cohorts of infants born through MSAF: 742 infants born prior to 1975 who did not have intrapartum suctioning and 755 infants born after 1976 who received intrapartum oro- and nasopharyngeal suctioning. The incidence of MAS (~2%) and the presence of meconium below the cords (~36%) were equal in both groups. Afterwards, the authors conducted a prospective observational study of 438 consecutive infants born through MSAF: 221 received the suctioning before delivery of the shoulders, and 217 did not. All were tracheally suctioned per their policy. There was no statistically significant difference in the incidence of MAS in the two groups (10% vs 7%) (10).

A more recent prospective randomized controlled trial by Vain et al (11) has shown that intrapartum upper-airway suctioning by the obstetrician makes no difference in the incidence of MAS (4% in both groups). Based on this study, changes were made to the neonatal resuscitation guidelines in 2005 (12): routine intrapartum suctioning (before the delivery of shoulders) was no longer recommended *routinely* for all babies born through MSAF (*Table 1*). It is of interest that there was disagreement among members of the Neonatal Resuscitation Program steering committee on this issue, and they emphasized that intrapartum suctioning was not contraindicated but merely no longer recommended based on the most current published evidence (13).

From our experience, it needs to be pointed out that although there is no benefit from this intervention, there is also no apparent harm. We would argue that since clearing of the upper airway will be required in depressed babies after hand-off to the neonatal team prior to intubation for tracheal suctioning, it is wise to proceed with suctioning of the upper airway *before* the shoulders and chest are delivered. At the same time, it is important not to delay the *immediate* hand-off of the infant to the neonatal team immediately after birth for appropriate airway suctioning and management.

### Further studies of routine intubation in the delivery room

The notion that delivery room intratracheal suctioning does not prevent all cases of MAS was published in 1997 (14). In this study, which was a retrospective chart review, the autopsies



**Figure 2.** Treatment algorithm used at Baylor University Medical Center. Vigorous was defined as a heart rate >100 beats per minute, good tone, and normal respirations. Suctioning of the upper airway after delivery of the head continues, although it is no longer included in the recommendations of the American Academy of Pediatrics' Neonatal Resuscitation Program (19).

of eight infants born through MSAf were compared with nine controls who were not born through MSAf. All the deaths occurred within 48 hours of birth. Seven out of eight infants born through MSAf underwent intratracheal suctioning. The striking difference between the two groups was the pulmonary vascular muscular media thickness in the infants with MAS. The authors concluded that the infants with MAS had in utero hypoxia that caused gasping and aspiration as well as the changes in the vascular muscular media of the pulmonary arteries. *MAS may be a prenatal rather than a postnatal disease* (8, 14).

Linder and colleagues performed a trial (15) in which vigorous infants born through MSAf were randomized to either intubation and suctioning or expectant management. None of the babies who were not intubated developed MAS, whereas 4 out of 300 who were intubated and suctioned developed MAS. Another large, multicenter, prospective, randomized controlled trial (16) addressed the same question, and the conclusions were compared with expectant management. Intubation and suctioning of vigorous babies born through MSAf (even of the thickest consistency) did not result in a decreased incidence of MAS. Based on this study, changes were made to the neonatal resuscitation guidelines in 2000 (17) (Table 1). If an infant born through MSAf has a normal respiratory effort, normal muscle tone, and a heart rate >100 beats per minute, no intratracheal suctioning should be performed. This conclusion was affirmed by a Cochrane review of the topic published in 2001 (18).

Whether a study of nonvigorous babies could ever be ethically carried out is debatable, but based on the above discussion, it is clear to us that depressed infants should be suctioned in the delivery room.

## THE BAYLOR EXPERIENCE

At the beginning of 1997, we opted for a selective approach to suctioning: only infants who were depressed based on a heart rate <100 beats per minute, poor tone, and poor or no respiratory effort were intubated and suctioned. The babies who were vigorous, even if born through thick meconium, were no longer intubated and suctioned. Prior to 1997, the only group of infants not intubated and suctioned were vigorous infants who had thin meconium. All other infants were routinely intubated and suctioned irrespective of heart rate or tone. The algorithm currently used is shown in Figure 2.

To evaluate the effectiveness of this new strategy, we reviewed our experience in the 3-year period from 1994 through 1996 and compared outcomes with those in infants born in 1997 and 1998 after implementation of selective suctioning.

## Methods

The charts of all mothers who delivered at >36 weeks at Baylor University Medical Center between 1994 and 1998 were reviewed by one of the authors (DC). The Apgar scores, treatment modalities used, and outcome were recorded. MAS was defined both radiographically and clinically based on three criteria: 1) being born through MSAf; 2) having an abnormal chest radiograph; and 3) having respiratory distress that persisted beyond 24 hours of age and required oxygen. For criterion 2, the admission chest radiographs of all infants admitted to the NICU after delivery through MSAf were retrospectively reviewed by a staff radiologist who was unaware of the clinical diagnosis or reason for NICU admission; 35 radiographs were abnormal.

Statistical significance was determined between groups using the Student *t* test for continuous variables and the chi-square test for categorical variables.

## Results

During this 5-year time period, there were 20,047 live births, and 1844 (9.2%) of the infants were born through MSAf. As expected, there was a significant difference in the number of infants who received tracheal suctioning between the two time periods. However, there was no statistically significant difference in the number with a diagnosis of MAS (Table 2).

The Apgar scores of infants born through MSAf in 1997 and 1998 were lower in suctioned infants versus nonsuctioned infants but were similar at 5 minutes ( $5.9 \pm 2$  for suctioned vs  $8.1 \pm 1$  for nonsuctioned at 1 minute [ $P < 0.01$ ] and  $8.6 \pm 0.9$  vs  $8.9 \pm 0.4$  at 5 minutes [not significant]). The lower 1-minute Apgar score was related to intubation and suctioning. It is well known that suctioning can lead to vagal-induced bradycardia. However, by 5 minutes the infants had comparable Apgars in the two time periods of the study.

## CONCLUSIONS

MAS is a serious disorder of the newborn. It is no longer considered a purely postnatal disorder that is a result of postnatal aspiration preventable by immediate tracheal suctioning in the delivery room. Rather, it is considered a disorder that has antepartum as well as intrapartum and neonatal causes. Most

**Table 2. Comparison of infants born through MSAf under different tracheal suctioning policies at Baylor University Medical Center**

Variable	1994–1996*	1997–1998†	P value
Total live births	11,849	8198	—
Born through MSAf	1088 (9.2%)	756 (9.2%)	NS
Received tracheal suctioning	283 (26%)	102 (13.5%)	<0.01
Diagnosed with MAS	15 (1.4%)	8 (1.1%)	NS
Required mechanical ventilation	9/15	6/8	NS
Required nitric oxide or ECMO	3/15	0/8	NS
Deaths	1/15	0/8	NS

\*Tracheal suctioning was provided to all depressed infants and all infants (even vigorous ones) with thick meconium. When possible, the obstetrician performed upper airway suctioning on all infants before delivery of their shoulders.

†Tracheal suctioning was provided to all depressed infants regardless of meconium consistency. When possible, the obstetrician performed upper airway suctioning on all infants before delivery of their shoulders.

NS indicates not significant; MSAf, meconium-stained amniotic fluid; MAS, meconium aspiration syndrome; ECMO, extracorporeal membrane oxygenation.

likely, the most severe cases occur prior to the first breath, with intrauterine gasping and aspiration induced by hypoxia and acidosis (8). The current thinking on prevention of this disorder requires that depressed infants be tracheally intubated and suctioned in the delivery room. Clearly, this approach will not prevent all cases but may attenuate the severity of MAS.

Our experience at Baylor applying a selective approach to tracheal suctioning was reviewed over a 5-year period in more than 1800 infants born through MSAf. Our overall incidence of MAS was low and did not change after introduction of selective tracheal suctioning only in depressed infants. Whether this approach can be modified further cannot be determined by published studies or our experience. Until further studies can be done evaluating the utility of routinely suctioning the depressed newborn, it is our practice to suction the upper airway before delivery of the shoulders and then hand off the infant promptly for neonatal evaluation. We intubate and suction those infants who have a heart rate <100 beats per minute with poor tone and little or no respiratory effort.

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